SMUTGRASS (*Sporobolus poiretii* [Roem. and Schult.] Hitchc.) CONTROL WITH GRAZING MANAGEMENT SYSTEMS

By

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Dedicated to my wife
Augusta

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[Roem. and Schult.] Hitchc.)
CONTROL WITH GRAZING MANAGEMENT SYSTEMS

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The purpose of the experiment was to determine the effect of grazing management upon the persistence of smutgrass (*Sporobolus poiretii* [Roem. and Schult.] Hitchc.) and whether manipulation of length of rotation cycle and grazing pressure could be used to control this grass weed. Five lengths of rotation cycle (grazing period plus rest period) and five levels of grazing pressure were superimposed upon the smutgrass-infested bahiagrass (*Paspalum notatum* Flugge) pastures.

The grazing treatments were an incomplete factorial set, arranged in a response surface design of 13 treatment combinations of rotation cycles and grazing pressures. On one set of pastures, molasses was sprayed in an attempt to increase the acceptability of the smutgrass to the grazing animal; the second set was not sprayed and was considered the control.

Equal quantities of molasses and water were mixed and sprayed on the standing forage of the molasses set of

pastures at the rate of 3,644 liters/ha prior to introducing the animals.

Lengths of rotation cycles were 0, 14, 28, 42, and 56 days. Grazing pressures were measured in terms of residual dry matter/ha (RDM) remaining in the pasture after grazing periods. The target RDM levels were 0.5, 1.3, 2.1, 2.9, and 3.7 metric tons/ha in 1976 and 0.5, 1.0, 1.5, 2.0, and 2.5 metric tons/ha in 1977.

The quantity of smutgrass as percent ground cover measured with the line transect and permanent quadrat methods was not affected by the length of rotation cycle (P = 0.82) nor by spraying molasses (P = 0.74). However, as grazing pressure was increased the smutgrass ground cover was reduced. Ground cover was first measured prior to application of the treatments in early April 1976. Measurements were again made in June and October of 1977.

The estimated ground cover in April 1976 of 16.33% was reduced by June 1977 to 5.36, 7.01, 6.94, 2.96, and 0.26% (P = 0.0001) from the lowest to the highest grazing pressure, respectively (highest to lowest RDM). In October 1977, the smutgrass ground cover for the five levels of grazing pressure was 5.65, 5.82, 5.57, 2.63, and 0.30% (P = 0.0001).

The grand means for all treatments in June and October 1977 were 4.27 and 3.91% smutgrass ground cover, respectively.

INTRODUCTION

Agriculture has been described as competition with weeds. The energy available for plant growth on a given area could be used by the crop to its maximum capacity if it were not for weed competition. Crop production is, therefore, reduced in direct proportion to the amount of weed production per given land area. Weeds compete with crops for water, nutrients, light, gases, and space.

Reduction of production caused by weeds and the cost of their control constitute two of the largest factors in production of food, feed and fiber. The U. S. Department of Agriculture (USDA) estimated the losses of various crops due to weeds to be over 5 billion dollars in the United States (USDA, 1965). Buchanan (1975) estimated these losses to be as high as $10 billion in 1975 in the United States and pointed out that some estimates place U. S. losses at about 10 to 20% of the total crop yields. Losses from weeds are equally divided between reduction in crop yields and cost of controlling them. About one-half of all tillage operations are solely for weed control. Besides the reduction in yields, weeds reduce land value, lower quality of crops and animal products, cause deaths, and offer habitat and protection for insects and diseases.

Weed control is a major need in any management program. The primary objective of weed control in pastures is to manipulate selectively the canopy to eliminate undesirable plant species while maximizing the production of the desired ones. The complexity of weed control requires inputs from a wide variety of specialties such as plant ecology and physiology, management, and economics. Recommended weed-control measures must be implemented as long-term programs without damaging desirable plants.

Smutgrass (Sporobolus poiretii [Roem. and Schult.] Hitchc.) is a very serious weed in many pastures, although it would only be considered a real threat to forage production 5 to 10 years after being introduced into a given area. Its control in pastures has long been recognized as important in Florida, where for the past 25 years several control methods have been developed. These methods are generally mechanical, chemical, or a combination of the two. However, such methods have had erratic and unsatisfactory results since they are not selective for the control of the smutgrass.

In the search for a new, inexpensive, and efficient method of smutgrass control, an experiment was established in which five grazing management systems were studied in combination with molasses sprayed on the standing forage. The experiment was carried out for 2 successive years from which the results obtained during the second year (1977) are reported in this dissertation. The results of the first year were reported by Valle (1977).

LITERATURE REVIEW

Smutgrass

Most weed problems in grazing lands result from man's introduction of exotic plants into new areas. According to Hitchcock (1950) smutgrass was introduced into the United States from tropical Asia as an ornamental plant. It is now a serious weed in many pastures of the southeast, particularly on the sandy soils of Florida.

Smutgrass is a perennial grass with culms erect, solitary, or in small tufts, growing 30 to 100 cm tall. It is named after a Lyphomicete, Biopolaris (Helmintosporium) ravanelii (Curt.) Schoemaker (Luttrell, 1976) which often infects the plant, covering the inflorescence with smut. It is also found in patches on the leaves. The seeds are smut-free. The smutgrass panicle is spike-like, more or less interrupted, and 10 to 40 cm long with bunches appressed or ascending; spikelets somewhat unequal and about 1.7 to 2.0 mm long. The seeds are reddish when mature and remain for some time sticking to the panicle by the mucelagineous pericarp (Hitchcock, 1950) depending, however, on the weather and mechanical forces (Currey and Mislevy, 1974).

Seeds are spread by water, wind, and by adhering to the coats of livestock. Seeds are produced continuously from

May to December, with flowering, immature, mature, and shattering seeds occurring simultaneously on a single inflorescence of one plant (Currey and Mislevy, 1974). The number of seeds produced by a single panicle is over 1,400 and a mature plant can produce in excess of 45,000 seeds. The average germination, however, is only about 9% as indicated by Currey et al. (1973).

Smutgrass is a very successful weed due to 1) the large number of seeds produced per season, 2) the continuity of seed production, 3) variability of seed dormancy with germination over an extended period of time, and 4) the high degree of unpalatability to the grazing animal.

Smutgrass is adapted to most soil types and to subtropical and temperate climates where rainfall exceeds 40 inches annually (Riewe et al., 1975). It has invaded a considerable area of pastures and rangeland across the southeastern United States from Virginia to Tennessee, Oklahoma, Florida, and Texas, where it is a very undesirable grass weed. Smutgrass is also found in Cuba (Hitchcock, 1906), Argentina and Uruguay (Roseveare, 1948), Puerto Rico (Molinari, 1949), Guatemala (Swallen, 1955), and Brazil (Sacco, 1964). Blanco (1975) reported two species of *Sporobolus* in Brazil, *S. poiretii* and *S. indicus* (L.) R. Br.

The first reported potential threat of smutgrass to Florida's forage production and quality was from McCaleb et al. (1963). Currey and Mislevy (1974) in a survey of some

central and south Florida counties indicated that 75% of the improved pasture was heavily infested with smutgrass with an average level of infestation of 38%.

Although its establishment is slow, it can become the dominant species in the field due to its low acceptability by livestock. As stated by McCaleb et al. (1963), the lack of palatability of smutgrass is particularly evident on the mineral soils of Florida and Georgia, and as added by Currey et al. (1973), this characteristic has helped to account for the high level of infestation presently observed in Florida.

The cause of smutgrass unpalatability is not known. It may be due to the high fiber content of the leaves which in a mature plant can be as high as 82%, according to Mislevy and Currey (1975).

Smutgrass Control

Control of smutgrass has been attempted for about 25 years in Florida by different methods. The most frequent ones were mechanical, cultural, chemical, and combinations of the mechanical and chemical methods as reported by McCaleb et al. (1963) and Currey and Mislevy (1974). The first study of the control of smutgrass by grazing management in Florida was conducted by Valle (1977) but no conclusive information is available in his report.

McCaleb et al. (1963) used mechanical methods to control smutgrass in Florida as early as 1955. They reported the

use of rotary mowing at a 3-inch height at intervals of 1, 2, 3, and 4 weeks. They concluded that mowing at weekly intervals resulted in some reduction of plant size but with subsequent recovery after termination of the treatment. They also reported the use of cultivation and complete renovation of the pasture, but the results were again unsatisfactory because new plants grew from seeds already in the soil. In Louisiana, Carter (1961) reported 90 to 95% reduction of smutgrass by using a modified rotary tiller. There are few other reports available in the literature (Currey and Mislevy, 1974; Klingman and McCarty, 1958) concerning the use of mechanical methods to control smutgrass, but all concluded that the results obtained by this method were unsatisfactory.

Many chemicals have been evaluated to determine their effects on smutgrass. McCaleb et al. (1963) screened six different chemicals for their herbicidal effects and efficiency on control of smutgrass. They reported that dalapon (2,2-dichloropropionic acid), monuron TCA (3-[p-chlorophenyl]-1, 1-dimethylurea mono [trichloro] acetate), and monuron (3-[p-chlorophenyl]-1, 1-dimethylurea) were promising products for the control of smutgrass.

Selective smutgrass control in bermudagrass-dallisgrass pasture, respectively, Cynodon dactylon (L.) Pers. and Paspalum dilatatum Poir., was tried by Smith et al. (1974) for two growing seasons with three herbicides —atrazine (2-chloro-4-[ethylamino]-6-isopropylamino-S-triazine),

bromacil (5-bromo-3-sec-butyl-6-methyluracil), and MSMA (monosodium methanearsoate) at different levels of application for each chemical. They reported that 83 to 93% of the smutgrass control was obtained with a single application of atrazine or bromacil. However, 38% of the bermudagrass and 28% of the dallisgrass were injured. The maximum control of smutgrass obtained with MSMA was 63%, but 89% of the dallisgrass was killed.

A trial on smutgrass control with application of dalapon at 5.6 kg/ha and paraquat (1, 1'-dimethyl-4-4'-bipyridinium) at 0.56 kg/ha was reported by Riewe (1974). The application of these chemicals in late summer on a dallisgrass-common bermudagrass sod gave a minimum of 80% control of smutgrass with dalapon effects prevailing for more than 18 months after application. In Mississippi, Smith et al. (1975) reported that spring application of dalapon and diuron (3-[3,4-dichlorophenyl]-1,1-dimethylurea) controlled 90% of the smutgrass in a bermudagrass pasture. Riewe et al. (1975) reported a trial in which they used simazine (2-chloro-4,6-bis [ethylamino]-S-triazine), MSMA, and atrazine each at 2.24 kg/ha rate, bromacil and glyphosate (N-[phosphonomethyl] glycine) at 1.12 kg/ha, asulan (methyl sulfanylcarbamate) at 3.36 kg/ha, and dalapon at 5.56 kg/ha. Each herbicide was applied at three different times—March, May, and August. March and May applications resulted in significant, but inconsistent control of the smutgrass by dalapon and glyphosate.

August application gave more effective and consistent control of smutgrass. The effectiveness of herbicides was in the order of dalapon = glyphosate > atrazine > bromacil > asulan > simazine = MSMA = untreated check. By the following summer only dalapon, glyphosate, and atrazine were still providing significant control. However, Smith et al. (1974) were skeptical about using dalapon or glyphosate because in addition to controlling smutgrass these herbicides kill or severely injure the desirable grasses.

Johnson (1975) tried herbicides to control smutgrass in turfgrass. He reported on the use of atrazine at 2.2 kg/ha in two applications and MSMA alone at 2.2 kg/ha or in combination with 2,4-D ([2,4-dichlorophenoxy] acetic acid) at 0.6 kg/ha, and concluded that in each application at least 70% of the smutgrass was controlled. Similarly to results by other workers, the herbicides either killed or injured the desirable grasses.

Grazing Management to Control Weeds

Effective control of weeds may be obtained by mechanical means such as mowing or cultivation, or by chemical means by applying herbicides. However, in any situation, costs must be considered (Leach et al., 1976). Chemical control may be essential where toxic weeds, hazardous to livestock, have become established. In other cases, where no toxic plants are present, grazing management may be valuable. Michael

(1970) pointed out that the use of grazing management as a tool for weed control has barely begun in Australia. Yet this is an important field requiring much study, especially in relation to grass weeds. Smith (1968) related control of barleygrass (Hordeum leporinum Link.) by grazing management and stated the advantages of this method over chemical control are that it is cheap and the weed is a useful source of forage in its early growing stage.

In Australia, Michalk et al. (1976) studied the effect of different stocking rates under six grazing management systems on the control of barleygrass and concluded that heavy grazing in late winter increased the production and number of seedheads of the barleygrass in the pasture per unit area. However, when heavy grazing was applied in early fall a great decrease in the weed population was observed.

Deferred grazing until winter or spring was very effective in the control of slender thistle (Cardus pycnocephalus L.) in an improved pasture in southern Tasmania as reported by Bendall (1973). He added that spring grazing favorably altered pasture botanical composition by increasing the frequency of perennial ryegrass (Lolium perene L.) and subterranean clover (Trifolium subterraneum L.), and by reducing the frequency of the weed. He also pointed out that of the successful treatments, deferred fall grazing is the most practical system for incorporation into the farm management procedure for the control of the slender thistle because such a program has the advantage of being

less expensive than chemical methods and favors general pasture improvement. Laycock (1970) reported that fall grazing was a valuable method for range improvement by being effective in the control of sagebrush on a sagebrush-grass range. It was also less expensive than mechanical and chemical methods.

Valle (1977) reported the use of five grazing management systems to control smutgrass. He used 0.5, 1.3, 2.1, 2.9, and 3.7 metric tons/ha of residual dry matter as grazing pressure levels in combination with rotation cycles of 0, 14, 28, 42, and 56 days to control smutgrass in a pasture of bahiagrass (Paspalum notatum Flügge.). His results indicated that heavy grazing pressure was a very promising treatment to control smutgrass but the length of rotation cycle did not show a significant effect.

Myers and Squires (1970) observed the effect of grazing on the control of barleygrass for three successive fall seasons in an irrigated pasture of subterranean clover. They compared the effect of grazing, beginning at 10, 20, and 40 days after irrigation had started and concluded that the best barleygrass control was obtained with the 20-day treatment. Deferred grazing for 10 days was less successful because the animals showed a tendency to graze old, dead plant material to the detriment of the barleygrass in its early growth stage. They concluded also that the total control of barleygrass can be achieved within a 2-year period by using the 20-day deferred grazing method.

Benefits from Weed Control

Beneficial effects of weed control in pastures depend on the efficiency of the method used for the control itself and on the favorable effects of the control on the desirable species. Klingman (1970) pointed out that a method to prevent and eliminate weeds is the most important factor to maximize forage production and quality in a pasture. This is the highest efficiency required from a pasture and is achieved by integrating all beneficial practices into the management system.

Controlling weeds in pasture should increase forage quality and intake by livestock. Smith et al. (1974) determined the quality of forage produced after controlling smutgrass in a bermudagrass-dallisgrass pasture. They observed significantly higher soluble cell contents, and lower acid and neutral detergent fiber fractions in the treated plots as compared with the control treatment. Based on the nutritive value index (NVI), they suggested that intake of digestible dry matter should be higher in the smutgrass-controlled pastures.

Six weeks after paraquat was sprayed on a bermudagrass pasture to control weeds, yield, quality, and *in vitro* digestibility of the forage produced were increased (Monson, 1977).

Klingman and McCarty (1958) reported increases in forage consumption of 47 and 19% when pastures were sprayed

with chemicals and mowed for weed control. The dry matter intake was 748 and 608 kg (1650 and 1340 lb) on the sprayed and mowed treatments, respectively, and 510 kg (1124 lb) on the untreated control plots.

In a 4-year study, Morrow and McCarty (1976) observed the influence of green sagewort (Artemisia campestris L.) and other broadleaf weeds on forage production in Nebraska. Chemical treatment increased forage production by 42% and controlled 97% of the weeds in plots receiving two consecutive annual applications of herbicides. Forage production was increased up to 150 kg (330 lb) of dry matter/acre on plots receiving herbicides alone, and up to 300 kg (660 lb) of dry matter/acre when herbicide applications were followed by N fertilization. They pointed out that herbicides and fertilizer can be effectively used to increase forage production, but that they will not correct the effect of mismanagement that results in weedy pastures.

In Nebraska, Klingman and McCarty (1958) reported that the use of 2,4-D was more efficient than mowing for the control of broadleaf weeds. Three annual 2,4-D applications reduced weeds by 70% while mowing alone resulted in a reduction of 30%. Combining an annual application of 2,4-D with plowing and seeding reduced broadleaf weeds more than 90%.

Scholl and Brunk (1962) investigated the competition of weeds with birdsfoot trefoil (Lotus corniculatus L.). They compared no-weed control with all weeds removed in

the early stage of growth. Where weeds were not controlled yield for the first year was 176 kg (389 lb) of dry matter/acre whereas treatments with weeds completely controlled produced 1,062 kg (2,342 lb) of dry matter/acre. In the second year, the yields were 1,578 and 2,963 kg (3,480 and 6,533 lb) of dry matter/acre for the no-control and full-control treatments, respectively.

Botanical Composition Changes by Grazing

One of the most important factors to consider when controlling weeds is the subsequent change in botanical composition. This is also of great importance in grazing experiments since the presence of animals in a pasture affects its botanical composition through defoliation, excretion, and trampling. As stated by 't Mannetje et al. (1976) even the so-called "pure stand," pastures will usually contain varying amounts of other species and that botanical composition is important since individual species or cultivars vary in feeding value, in content of harmful substances, and in their reaction to environmental and management factors.

Changes in botanical composition were studied by Bryan (1970) on mixed pastures under high and low stocking rates. Under high stocking rate *Paspalum dilatatum* Poir. and weeds increased from 24 to 33% and 14 to 22%, respectively, whereas *Chloris gayana* Kunth. decreased from 18 to 7%. Cameron and Cannon (1970) also observed changes in botanical

composition as a result of seven increasing stocking rates from 4.9 to 19.8 sheep/ha during 6 years, 1963 to 1968. In their study, subterranean clover increased from 30 to 70% under the lowest stocking rate and decreased from 30 to 10% under the highest stocking rate. At the same time, perennial ryegrass, initially the main component of the pastures representing 20 to 40% of the sward, decreased to a trace under every stocking rate imposed. Poa annua L., initially absent in the pastures, in 1968 ranged from 0 to 30% in the lowest to the highest stocking rate treatments.

Serrao (1976) studied the response of Desmodium intortum (Mall.) Urb-'Coastcross-1' bermudagrass mixture to different levels of grazing periods, rest periods, and grazing pressures. He observed that the legume percentage in the mixture increased with long rest periods associated with medium to light grazing pressure. Michalk et al. (1976) studied the effect of different stocking rates under six grazing management systems. He reported that dry matter production was not affected by the different treatments, but that a marked effect of the treatments on the botanical composition of the pastures was observed.

Ritson et al. (1971) observed changes in botanical composition of a mixture of Townsville stylo (Stylosanthes humilis H.B.K.), perennial grasses and annual grasses when stocking rates of 0.41 and 0.83 cow/ha were imposed. They reported that under the lower stocking rate perennial

grasses became dominant while the annual grasses became dominant under higher stocking rate along with the Townsville stylo.

The effects of rotational grazing compared with the continuous grazing management systems upon the changes in botanical composition of pastures were studied in Nebraska from 1949 to 1969 by McCarty et al. (1974). They reported that under rotational grazing relatively few weeds invaded the pasture and only a small amount of blue grama [Bouteloua gracilis (H.B.K.) Lag. ex-Stent.] and sand lovegrass [Eragrostis trichodes (Nutt.) Wood] persisted. In 1969, the mixture consisted primarily of big blue-stem (Andropogon gerardii Vitman), Indiangrass [Sorghastrum nutans (L.) Nash.] and switchgrass (Panicum virgatum L.). In the continuously grazed, warm-season grass plots, the main desirable species was blue grama.

Ottosen et al. (1975) studied the changes in botanical composition of a mixture of tropical grass-legume association by comparing strip with continuous grazing. Both grazing management systems caused marked changes in botanical composition of the pastures. Legumes decreased from 24 to 16% in the strip-grazed plots whereas in the continuously grazed ones the legumes increased from the initial 24 to 38%. They pointed out that after the experiment was terminated, both grass and legumes populations recovered without any differences resulting from the previous grazing systems.

Different species may have different resistance and competitive power to dominate the botanical composition of swards when growing in mixed pastures. Thus, Torssell et al. (1976) reported changes in botanical composition of swards due to the relative persistance of the species growing together. They observed that some species like Stylosanthes hamata (L.) Tamb. would dominate Digitaria ciliaris (Ritz) Koel. and that these two species were mutually exclusive. The same behavior was observed for D. ciliaris in relation to S. humilis with the former being more competitive than the later when they were growing together. Therefore, the grass overpowered the legume. Torssell et al. (1976) concluded that these two pairs of species were mutually exclusive in their associations.

Effects of Spraying Molasses

Changes in botanical composition may be altered by inducing modifications to the grazing habits of the animals. Spraying molasses or other supplements on standing forage may increase the pasture acceptability and its consumption by livestock. The direct application of molasses on unpalatable pasture was reported by Loosli and McDonald (1958) in South Africa. They observed the beneficial effects of increased intake of the sprayed forage by livestock. Spraying molasses would also be helpful to control weeds. Plice (1952) advised farmers to take advantage of this practice to get rid of weeds, or unpalatable, poor quality forage.

Willoughby and Axelsen (1960) reported changes in intake of preferred and initially non-preferred components of pastures. Spraying molasses in strips made the animals graze heavily on them, increasing the intake of both preferred and non-preferred species while the whole pasture was only lightly grazed for its most palatable components. Hence, only small areas of pasture should be sprayed daily to have the beneficial effects of spraying (Coombe and Tribe, 1962). Urea-molasses sprayed on native pasture with many unpalatable species increased considerably their consumption by grazing animals, as reported by Pope et al. (1955). They pointed out that spraying small areas at one time led to more uniform grazing since spraying large areas resulted in an incomplete utilization of the sprayed forage. Valle (1977) reported little or no effect of molasses sprayed on standing smutgrass. He mentioned that, although the grazing animals preferred the sprayed pastures shortly after spraying molasses, these pastures were no different from the control non-sprayed plots at the end of the grazing period. He speculated that the low rate of molasses applied was the reason for the lack of response to molasses. Coombe and Tribe (1962) pointed out that part of the sprayed molasses goes to the ground and part is washed off the foliage and wasted. This was considered one of the disadvantages of the practice by these authors. In addition, they pointed out technical difficulties in spraying

especially when pasture areas are large, stocking rates are low, and the soil surface is rough. Mostert (1959) mentioned the importance of spraying only thick stands to avoid waste. Loosli and McDonald (1958) reported that immediately after application, only 16.5% of the sprayed molasses could be recovered from the herbage.

Results obtained from different products sprayed on standing forage varies. Plice (1952) compared table-sugar, black-strap molasses, sorghum molasses, and corn syrup sprayed on weeds and grasses never preferred by grazing animals. He reported that the cattle easily discovered the sprayed plots and grazed them in the following order of preference: Black-strap molasses, sorghum molasses, table-sugar, and corn syrup. In Australia, pastures sprayed with urea, molasses, or urea-molasses mixture resulted in increased removal of the abundant, non-preferred component of the pasture (Phalaris sp.) primarily when molasses alone was applied (Willoughby and Axelsen, 1960). They concluded that spraying affected forage intake in three different ways: 1) by providing a supplement, 2) by altering the amount of forage consumption, and 3) by increasing or decreasing the quality of forage depending on whether the nonpreferred components are higher or lower than the preferred ones in nutritive value.

Bishop (1959) compared the effects of three different rates of molasses-urea mixture sprayed on pastures. The

rates were 3.78 liters (1 gallon) of the mixture per 9.2 to 13.7 m^2 (10 to 15 $yards^2$), 3.78 liters per 45.7 m^2 (50 $yards^2$), and 3.78 liters per 91.4 m^2 (100 $yards^2$). He reported that the medium level of application gave the best results and that, at the 3.78 liters per 91.4 m^2 much of the grasses remained ungrazed and the sprayed mixture was wasted. On the other hand, at the 3.78 liters per 9.1 to 13.7 m^2 the grazing was too short and undesirable. He pointed out that very short grazing is particularly undesirable on sandy soils where grass roots can easily be pulled out.

Foliar application of urea, molasses, and monosodium phosphate on carpetgrass (*Axonopus affinis* Chase) was studied by O'Bryan (1960). He sprayed the supplements on strips and observed that the animals showed preference to graze these strips immediately after being sprayed. However, he mentioned that the treatments failed to prevent the selective grazing also observed in the non-treated control. The 10 to 12% protein-containing forage was grazed first during the first year of the experiment. In the second year, the forage grazed first was that with 8% or more protein content. The frequency of spraying, heavy dews, and intermittent rainfall, associated with the low palatability of the carpetgrass and the high selectivity of the animals were the factors mentioned by O'Bryan (1960) to explain the low effect of the treatments.

Spraying native pasture with molasses and urea twice a week was reported by Christiansen (1965). He sprayed 12.5% of the pasture each time and observed that the dry coarse grasses, Paspalum quadrifarium, Lam. and Schizachyrium paniculatum (Kunth) Herter, were extensively grazed when sprayed. Wagnon and Goss (1961) reported increased consumption of dry forage when sprayed with molasses, or molasses-urea mixture. They sprayed 6.3 kg (14 lb) of the supplements/animal/week on thick stands of dry grasses and observed the complete utilization of the otherwise unpalatable and mostly ungrazed forages.

It appears that cattle change their grazing habits by continuous use of sprayed forage with supplements. Wagnon and Goss (1961) reported that cattle on frequently sprayed pastures continued to eat the old forage in preference to the new regrowth that became available after rain. The animals on untreated plots, however, started grazing the new plants as soon as they could be reached.

MATERIAL AND METHODS

A grazing experiment was conducted from April 1976 to October 1977 at the Beef Research Unit (BRU) of the University of Florida, Gainesville, Florida.

The soil at the experimental site is underlain by limestone of the Ecocene age having an overlay of acid, sandy, and loamy marine sediments (USDA, 1954).

According to USDA (1978), the soil of the experimental site belongs to Wauchula Series which is a member of the sandy, siliceous, hyperthermic family of Ultic Haplaquods. This soil has a sandy dark colored A1 horizon and a sandy light colored A2 horizon that total less than 76 cm (30 inches) thick over Bh horizon and an underlying Bt horizon with low base saturation.

Koger et al. (1961) reported that the average pH of this virgin soil was 4.9 in 1951. However, it varied with organic matter content with lowest pH values occurring in high organic matter soils. Organic matter content averaged 2.25% but ranged from 1 to 7%.

The climate is subtropical and humid, with a frost-free season averaging 276 days and an average annual precipitation of 1300 mm (USDA, 1954).

The experiment was conducted in a pasture of 'Pensacola' bahiagrass (*Paspalum notatum* Flügge), infested with smutgrass

(*Sporobolus poiretii* [Roem. and Schult.] Hitchc.) with white clover (*Trifolium repens* L.) appearing in the winter and crabgrass (*Digitaria sanguinalis* L.) in the summer. The degree of smutgrass infestation was visually estimated to be between 35 and 40% at the time the experiment was established, which is typical of many Florida pastures.

The area was subdivided into 82 pastures of 500 m^2 most of which were 50 m in length and 10 m in width (Fig. 1). The pastures were divided by means of five-strand barbed wire line fences and electric lateral fences. Water and mineral boxes were provided; water level was controlled in each container by a float valve.

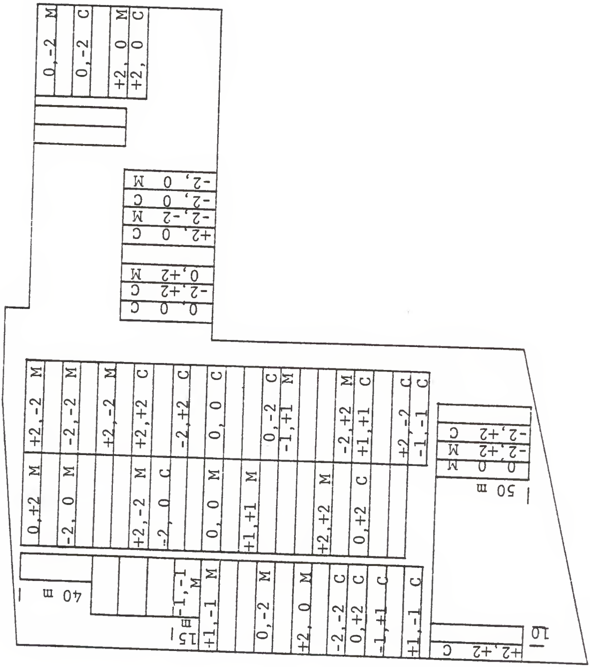
Treatments and Application

This dissertation is concerned with the results obtained in two of the treatments—control and molasses—which were part of a very large experiment. The other treatments are listed below but no details as they were established and results are presented.

Treatment 1. Control. In this treatment only grazing management systems were imposed.

Treatment 2. Molasses. In the rotationally grazed pastures, 1,360 kg/ha of molasses diluted by an equal volume of water were sprayed on the standing forage before each grazing period. On the continuous grazed plots, one fourth of the mixture was sprayed on one fourth of the plot each

Figure 1. Lay-out of the experiment showing a general view of the field and the plots that received control (C) and molasses (M) treatments with respective coded levels of rotation cycle and grazing pressure. The area is also known as pasture 2.1 in the B.R.U. Farm plan.


0,-2 M
0,-2 C
+2, 0 M
+2, 0 C
-2, 0 M
-2, 0 C
-2,-2 M
+2, 0 C
0,+2 M
-2,+2 C
0, 0 C
+2,-2 M
-2,-2 M
+2,-2 M
+2,+2 C
-2,+2 C
0, 0 C
0,-2 C
-1,+1 M
-2,+2 M
+1,+1 C
+2,-2 C
-1,-1 C
0,+2 M
-2, 0 M
+2,-2 M
-2, 0 C
0, 0 M
+1,+1 M
+2,+2 M
0,+2 C
-1,-1 M
+1,-1 M
0,-2 M
+2, 0 M
-2,-2 C
0,+2 C
-1,+1 C
+1,-1 C
0, 0 M
-2,+2 M
-2,+2 C
+2,+2 C
40 m
15 m
50 m
10

week. Molasses, before diluting in water, weighed 1.34 kg/liter. Spraying was carried out with a tractor-mounted boomles sprayer. The spray pump was operated at 2.5 kg/cm^2 pressure and driven at 4 km/hour. The field distribution of treatments 1 and 2 are presented in Figure 1.

Treatment 3. DSMN. Dalapon applied in the spring followed by mowing and N fertilization.

Treatment 4. DSBN. Dalapon applied in the spring followed by burning and N fertilization.

Treatment 5. DFMN. Dalapon applied in the fall followed by mowing and N fertilization.

Treatment 6. DFBN. Dalapon applied in the fall followed by burning and N fertilization.

Treatment 7. GHS. Cultivation with a Ground Hawg (a roto-tiller-type cultivator) in the spring.

Treatment 8. GHSN. Cultivation with a Ground Hawg in the spring and N fertilization.

Treatment 9. GHSbN. Cultivation with a Ground Hawg in the spring, seeding with bahiagrass, and N fertilization.

Treatment 10. GHFrN. Cultivation with a Ground Hawg in the fall, seeding with ryegrass, and N fertilization.

Treatment 11. BFDSMN. Burning in the fall followed by dalapon in the spring, mowing, and N fertilization.

Within the first 3 treatments—called main treatments—length of rotation cycle (constituted by grazing period and rest period combined) and grazing pressure were also experimental variables. Each of these factors was studied

at five levels. Length of rotation cycle was expressed in days and grazing pressure was defined as residual dry matter in metric tons/ha (metric tons RDM/ha) left after grazing periods.

The factors studied with their respective levels and codes are presented in Table 1 which includes the grazing pressures imposed in both 1976 and 1977. A range of plus or minus 0.2 metric ton RDM/ha was established for the projected residual dry matter left after grazing. Grazing periods lasted from 1 to 5 days for all treatments except for continuous grazed plots as shown in Appendix 1, Table 6, and were included in the number of days in the rotation cycle. Due to the size of the pastures, the animals could not be maintained continuously on the continuously grazed pastures. Simulation of continuous grazing was carried out as needed by turning the animals in and out of the pastures every few days to achieve the desired residual dry matter.

Experimental Design

The experimental design used was a modified central composite in two factors (length of rotation cycle and grazing pressure) arranged in a response surface design as shown in Fig. 2.

Combinations of the five levels of rotation cycle and the five levels of grazing pressure were superimposed upon each of the main treatments which made up 13 different

TABLE 1. Combinations of Length of Rotation Cycle and Grazing Pressure with their respective coded levels as superimposed upon the main treatments in the response surface design.

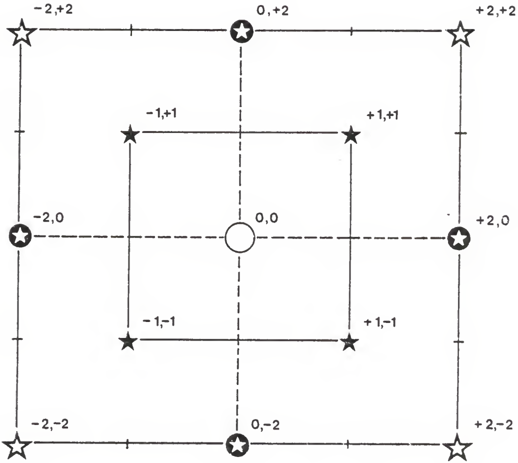
Points	Replications	Coded levels	Rotation cycle	Grazing pressure Projected 1976*	Grazing pressure RDM† 1977
	Nº		(days)	- metric tons/ha -	
		+1,+1	42	1.3	1.0
		+1,-1	42	2.9	2.0
Factorial	1	-1,+1	14	1.3	1.0
		-1,-1	14	2.9	2.0
		0,+2	28	0.5	0.5
		0,-2	28	3.7	2.5
Axial	2	+2, 0	56	2.1	1.5
		-2, 0	0‡	2.1	1.5
Center	2	0, 0	28	2.1	1.5
		+2,+2	56	0.5	0.5
		+2,-2	56	3.7	2.5
Corner	2	-2,+2	0‡	0.5	0.5
		-2,-2	0‡	3.7	2.5

†Residual Dry Matter left after each grazing period (±0.2 metric ton RDM/ha).

*After Valle (1977).

‡Continuous grazing simulated.

Figure 2. Schematic response surface design in two factors showing 13 treatment combinations with respective coded levels and the expected variances.



★ Factorial points-2^2 $\hat{VY} = 0.12$

☆ Corner points-2^2 $\hat{VY} = 0.39$

Axial points-(2)(2) $\hat{VY} = 0.25$

○ Center points $\hat{VY} = 0.14$

combinations or design points. The arrangement of the 13 combinations consisted of four factorial, four axial, one center, and four corner points (Table 1 and Fig. 2). All these combinations were replicated twice except the factorial points, which were not replicated, making a total of 22 pastures (experimental units) for each main treatment.

The center point (central treatment) was the combination of the length of rotation cycle of 28 days and grazing pressure equivalent to a residue of 1.5 metric tons RDM/ha. This combination length of rotation cycle and grazing pressure was also superimposed upon treatments 4 to 11 above (extra treatments), each replicated twice. All treatments were assigned at random to the pastures.

Experimental Animals

From 18 April to 18 July 1977, 35 Brown Swiss x Angus heifers and cows, with an average weight of 373 kg were used to graze the experimental pastures. On 18 July, due to higher forage production, the herd size was increased from 35 to 73 animals of similar category. On 29 August, 13 animals were removed from the experiment. The remaining 60 head stayed in the pastures until the conclusion of the experiment on 21 October 1977. Therefore, the grazing season of 1977 was 186 days.

The put-and-take technique was used to stock the pastures to the projected grazing pressure levels. The animals were assigned at random to graze the plots.

The animals were weighed each 28 days to monitor their body weights. By 26 September the animals had lost weight. They were subsequently given feed supplementation. It consisted of commercial pellets with 20% protein and 65% TDN fed 3 days/week at the rate of 2.26 kg/head. By the end of the experiment the animals had recovered their initial body weights; the average weight of animals in the herd was 376.5 kg.

Details about the experimental animals during the grazing season of 1976 were presented by Valle (1977).

Measurements

Residual Dry Matter

In order to estimate the residual dry matter on the pastures after each grazing period, a simple unweighted disk meter as described by Santillan et al. (1977) was used. Twenty-five measurements were made within each plot at each sampling time which is shown in Appendix 1, Table 6. A double-sampling procedure was used to calibrate the disk meter on two occasions, April and June 1977. It consisted of 145 measurements of the height of the vegetation with the disk followed by cutting, drying, and weighing the herbage under the measuring disk. An oven at 75°C was used to dry the samples for 48 hours before weighing. The values obtained for the height (X_a) and weight ($\hat{Y}_a$) were fitted to a linear regression model to give the conversion factor

necessary to estimate the dry matter left after each grazing by measurement of the residual vegetation height.

Botanical Composition

In order to study the changes in the smutgrass ground cover as affected by the treatments, two techniques were used: The permanent quadrat method and the line transect method as described by Canfield (1941) and modified as shown in Appendix 2.

Measurements with the permanent quadrat were made on the crown canopy area of the smutgrass at the beginning of the experiment to evaluate the degree of infestation of the experimental site.

The equipment used consisted of a 2.0 x 0.5 m (1 m^2) frame constructed of aluminum and subdivided by thin aluminum bars to give 100 equal squares of 10 x 10 cm for simplicity and accuracy in drawing the outlines of each smutgrass clump. The frame was supported above the canopy by four legs, each equipped with a lock screw which allowed the frame to be adjusted to either 20 or 30 cm above the ground. The outlines were drawn on acetate transparent sheets at the scale of 1 mm on the acetate to 10 mm of the frame. Later, the areas outlined on the transparencies were inked with India ink with the aid of a small silk-hair brush. The inked areas were measured by passing each transparency through an electronic leaf-area meter which is an instrument that utilizes an electronic method of rectangular approximation with 1 mm^2 resolution. The major

instrument components are a scanning head and a readout-control unit. Area data are accumulated on the readout-control unit display as the scanning head is passed over a masking object such as a leaf or the inked area of the transparencies.

In order to estimate the basal area of the initial smutgrass ground cover, a series of double samplings were carried out. After the crown-canopy areas of smutgrass within 54 extra quadrats were outlined, the smutgrass clumps were cut at ground level and the basal contours of the clumps were cut at ground level and the basal contours of the clumps were outlined. The outlines thus obtained were processed as described above and the data were fitted to a linear-regression model to give the factor to transform the canopy area (X_b) to basal area ($\hat{Y}_b$) of smutgrass as shown in the next chapter.

Measurements with the line-transect method were made at ground level on the basal area of the smutgrass during the spring and fall of 1977 as shown in Appendix 1, Table 7. The transector as described in Appendix 2 was used. Ten points were randomly marked on one of the lateral fences with electrician's tape. Parallel points were marked on the other lateral fence in such a way as to give 10 pairs of points per plot. A wire was stretched between each pair of marked points on the fences and the transector was then located under this wire. A 5-m long transect was made across the pastures on each pair of tape-marked points and therefore 50 m of line

transect were measured per plot. The whole botanical composition was measured on each plot but only the results obtained with the smutgrass are presented in this dissertation.

The data collected with the transector were in centimeters of intercepted plants by the line transects. This was then transformed into percentages by calculating the number of centimeters of each species out of 5,000 cm measured per plot.

RESULTS AND DISCUSSION

Residual Dry Matter

The use of the disk meter allowed the estimation of the grazing pressure levels attained at the end of each grazing period by measuring the height of the residual standing forage. The measurements were carried out independently of the species being present under the device and, therefore, the figures presented in Table 2 are averages of the sward height. The double-sampling procedure performed with this device made it possible to calculate the weight of the remaining forage on the plots through the equation

$$\hat{Y}_a = 14.95\ X_a \qquad (1)$$

where $\hat{Y}_a$ = estimated dry matter weight/0.5 m^2

X_a = height of the residual standing forage/0.5 m^2

This equation was obtained by forcing the intercept through the origin, assuming that for the height to be equal to zero, weight must also be equal to zero. To check this assumption, the data were fitted to a complete model ($Y = a + bX$). It was found that the slope was similar as in Equation 1 and that the estimated intercept was not different from zero ($P = 0.20$) indicating the validity of the assumption. The coefficient of determination for the

TABLE 2. Estimated and observed height of the sward after grazing periods for each Grazing Pressure and for each main treatment with respective means, standard errors (s), and coefficients of variation (C.V.).

Grazing pressure projected RDM†	Height/0.5 m^2						
	Estimated*	Observed					
		Control			Molasses		
(metric tons/ha)	(cm)	mean --- cm ---	s	C.V. (%)	mean --- cm ---	s	C.V. (%)
0.5	2.06	2.11	0.04	1.8	2.11	0.06	2.8
1.0	3.73	3.82	0.17	4.4	3.75	0.04	1.0
1.5	5.39	5.49	0.15	2.7	5.44	0.08	1.4
2.0	7.06	7.11	0.01	0.1	7.21	0.12	1.6
2.5	8.72	8.61	0.14	1.6	8.76	0.18	2.0

† Residual Dry Matter left after each grazing period (±0.2 metric ton RDM/ha).

* Estimated height/0.5 m^2 to achieve the projected GP.

complete model was $r^2 = 0.90$ and the standard error of estimate $s_{y \cdot x}$ was equal to 34.7 g for the same model.

The means of the height determined for each grazing pressure in both control and molasses treatments, as well as their respective standard deviations and coefficients of variation, are presented in Table 2. Examination of the data in Table 2 shows the high precision that was obtained with the disk meter in estimating the residual dry matter by the measurement of height as seen by comparing the observed values with the estimated ones.

Smutgrass Ground Cover

The initial smutgrass ground cover was evaluated by the permanent quadrat method on the crown-canopy area in early spring of 1976. It was found that 36.31±5.90% of the area was covered by smutgrass. This degree of infestation is within the range of the visual estimation made before the experiment was established and is also similar to that reported by Currey and Mislevy (1974) as typical of smutgrass infestation of pastures in central and southern Florida.

The double-sampling procedure carried out with the permanent-quadrat method as explained before made it possible to estimate the initial basal area ground cover of smutgrass through the equation

$$\hat{Y}_b = 0.45\ X_b \qquad (2)$$

where $\hat{Y}_b$ = estimated basal area ground cover, and

X_b = observed crown canopy area ground cover.

As for Equation 1, it was assumed that for basal area ground cover to equal zero, the crown-canopy area must be zero. Therefore, the intercept in Equation 2 was forced through the origin. The permanent-quadrat data were fitted to the complete model ($\hat{Y} = a + bX$) to check the assumption as it was done for Equation 1. It was found that the slope of the curve was similar as in Equation 2, and that the estimated intercept was not different from zero ($P = 0.30$) indicating that the assumption was correct. The coefficient of determination for the complete model was $r^2 = 0.88$ and the standard error of estimate was $s_{y \cdot x} = 2.5\%$.

The smutgrass basal area ground cover as estimated through Equation 2 was 16.33±2.65% as an average for the experimental site. This conversion was necessary in order to make subsequent comparisons of the initial smutgrass ground cover with the values measured with the line-transect method which were carried out on the basal area ground cover as indicated before.

Treatment Effects

During the year of 1976, the grazing-pressure levels imposed resulted in great changes of smutgrass ground cover as measured with the line transect in the spring of 1977. The observed values for the grazing-pressure levels

attained in 1976 and the smutgrass ground cover (in spring 1977) are presented in Table 3.

Since the experimental design used was a response surface, the data observed in both spring and fall were fitted to the quadratic model as follows:

$$\hat{Y}_{i12} = b_o + b_1X_1 + b_2X_2 + b_{11}X_1^2 + b_{22}X_2^2 + b_{12}X_1X_2$$
$$E_{i12} \qquad (3)$$

where $\hat{Y}_{i12}$ = estimated response in smutgrass ground cover (for Y_{112} = spring and Y_{212} = fall)

X_1 = grazing pressure levels,

X_2 = length of rotation cycles,

b_{ij} = regression ocefficients, and

E_{i12} = experimental error.

Results in Spring of 1977

When spring-collected data were fitted to Equation 3, the following result was found:

$$\hat{Y}_{112} = -7.014 + 10.717\ X_1 + 0.014\ X_2 - 1.841\ X_1^2 - 0.22\ X_1X_2.$$

The coefficient of determination obtained for this equation was $r^2 = 0.63$ and the standard error of estimate was $s_{y \cdot x} = 2.29\%$. There was no linear effect ($P = 0.82$) nor quadratic effect ($P = 0.97$) of the length of rotation cycle upon smutgrass ground cover, indicating that this factor did not result in reduction of smutgrass ground cover. The estimated coefficient for X_2^2 was left out

TABLE 3. Effect of combinations of grazing pressure levels and length of rotation cycle during the 1976 season upon the percentage ground cover of smutgrass in the spring of 1977.

Rotation cycles	Grazing Pressure-1976* (metric tons RDM/ha)			Smutgrass Ground Cover spring-1977 - (%)		
	Predicted†	Observed	Sd	Mean	Sd	C.V.
(days)						
0	0.5	0.825	0.068	0.12	0.09	
28	0.5	0.741	0.008	0.15	0.31	
56	0.5	0.809	0.043	0.52	0.81	
$\bar{X}$		0.791	0.057	0.26	0.49	188
14	1.3	1.378	0.016	2.29	1.56	
42	1.3	1.338	0.138	3.64	3.08	
$\bar{X}$		1.358	0.083	2.96	1.41	47
0	2.1	2.171	0.068	9.44	4.17	
28	2.1	2.197	0.068	6.83	1.25	
56	2.1	2.118	0.075	4.56	2.58	
$\bar{X}$		2.162	0.072	6.94	3.36	48
14	2.9	3.028	0.191	6.01	3.40	
42	2.9	3.079	0.031	8.02	0.87	
$\bar{X}$		3.053	0.115	7.01	2.33	33
0	3.7	3.835	0.069	6.64	2.52	
28	3.7	3.702	0.054	6.16	2.60	
56	3.7	3.744	0.114	3.29	1.78	
$\bar{X}$		3.761	0.095	5.36	2.61	48

† Residual Dry Matter left after each grazing period (±0.2 metric ton RDM/ha).

* After Valle (1977).

because it was 0 up to the 3rd decimal place. There was no interaction of grazing pressure and length of rotation cycle ($P = 0.11$). There were both linear ($P = 0.0001$) and quadratic ($P = 0.0001$) effects of grazing pressure and this factor was effective in reducing smutgrass ground cover.

Results in Fall of 1977

For the fall-collected data which are presented in Table 4, when fitted to Equation 3 the result was:

$$\hat{Y}_{212} = -5.891 + 11.249\ X_1 + 0.010\ X_2 - 2.443\ X_1^2 - 0.021\ X_1X_2$$

The coefficient of determination and the standard error of estimate for this equation were, respectively, $r^2 = 0.75$ and $s_{y \cdot x} = 1.49\%$.

As for the spring data, there were no linear ($P = 0.80$) nor quadratic ($P = 0.93$) effects for the length of rotation cycle factor. The interaction of length of rotation cycle and grazing pressure was also small ($P = 0.12$) and, therefore, not effective in reducing smutgrass ground cover. Besides confirming the observation in the spring, these results indicated that the length of rotation cycle was not an important factor in the control of smutgrass under the experimental conditions. Therefore, the length of rotation cycle was deleted from Equation 3. On the other hand, both the linear ($P = 0.0001$) and quadratic ($P = 0.0001$) effects of grazing pressure were very high. The observations with both the spring and fall data showed that grazing pressure was the most important factor to reduce the

TABLE 4. Effect of combinations of grazing pressure levels and length of rotation cycle during the 1977 season upon the percentage ground cover of smutgrass in the fall of 1977.

Rotation cycles	Grazing Pressure-1977 (metric tons RDM/ha)			Smutgrass Ground Cover fall-1977 - (%)		
	Predicted†	Observed	Sd	Mean	Sd	C.V.
(days)						
0	0.5	0.633	0.004	0.30	0.46	
28	0.5	0.642	0.016	0.19	0.37	
56	0.5	0.618	0.012	0.26	0.36	
$\bar{X}$		0.630	0.015	0.25	0.37	103
14	1.0	1.155	0.036	1.40	0.22	
42	1.0	1.109	0.004	3.86	1.10	
$\bar{X}$		1.130	0.030	2.63	1.56	59
0	1.5	1.608	0.024	6.40	3.47	
28	1.5	1.660	0.040	6.30	0.63	
56	1.5	1.635	0.023	4.01	1.06	
$\bar{X}$		1.630	0.033	5.57	2.24	40
14	2.0	2.128	0.000	5.93	2.33	
42	2.0	2.152	0.042	5.72	0.02	
$\bar{X}$		2.135	0.018	5.82	1.35	23
0	2.5	2.622	0.024	6.72	0.98	
28	2.5	2.601	0.061	5.46	1.01	
56	2.5	2.568	0.067	4.76	1.99	
$\bar{X}$		2.675	0.053	5.65	1.53	27

†Residual Dry Matter left after each grazing period (±0.2 metric ton RDM/ha).

smutgrass ground cover and it can be used as an effective and inexpensive method to control smutgrass infestation in pastures. These results agreed with the ones of Leach et al. (1976) and Smith (1968) that indicated grazing as a cheap and important tool to control weeds.

Control vs Molasses

In order to study whether the main treatments, control and molasses, were different from each other in the control of smutgrass, the combined treatments data were fitted to the model that follows:

$$\hat{Y}_{i13} = b_o + b_1X_1 + b_3X_3 + b_{11}X_1^2 + b_{13}X_1X_3 + E_{i13} \quad (4)$$

where $\hat{Y}_{i13}$ = estimated response in smutgrass ground cover (for $\hat{Y}_{113}$ = spring and $\hat{Y}_{213}$ = fall)

X_1 = grazing pressure levels,

X_3 = treatments (control vs molasses),

b_{ij} = regression coefficients, and

E_{i13} = experimental error.

Treatment Comparison in Spring

The results obtained in the spring were fitted to Equation 4 and the result was:

$$\hat{Y}_{113} = -7.219 + 10.786\ X_1 + 0.529\ X_3 - 1.774\ X_1^2$$
$$0.650\ X_1X_3$$

The coefficient of determination for the above equation was $r^2 = 0.59$ and the standard error of estimate was $s_{y \cdot x} = 2.41\%$. The calculated coefficient for the control

vs molasses factor revealed that the two treatments were not different from each other ($P = 0.74$). There was no effect ($P = 0.32$) for the interaction of control vs molasses factor and grazing pressure factor. This indicates that the control and molasses treatments gave essentially the same response in the reduction of smutgrass. The lack of effect of molasses as compared with the control treatment is similar to the results reported by O'Bryan (1960) who did not observe differences between sprayed and non-sprayed treatments. This is also in agreement with Valle (1977) who reported no apparent effect of molasses upon the control of smutgrass. He suggested that the low rate of molasses applied would have been the cause of the lack of effect observed. In order to check his hypothesis, the rate of molasses applied during the year of 1977 was three times the rate used by Valle (1977) during the year 1976.

Treatment Comparison in Fall

When the fall-collected data were fitted to Equation 4 the result was:

$$\hat{Y}_{213} = -5.616 + 11.095\ X_1 + 0.194\ X_3 - 2.328\ X_1^2 - 0.534\ X_1X_3.$$

The coefficient of determination for this equation was $r^2 = 0.72$ and the standard error of estimate was $s_{y \cdot x} = 1.55\%$. The coefficient calculated for the control vs molasses factor was not different from zero ($P = 0.86$) and the interaction of the control vs molasses factor and grazing pressure was also small ($P = 0.39$), indicating that spraying

molasses did not result in greater reduction in smutgrass ground cover than in the control treatment. This also negated the hypothesis of low rate of application of Valle (1977). Therefore, the data collected in both the control and molasses treatments were combined to form a single set of data. This set of data was used for fitting the Equation 3 to study the importance of the length of rotation cycle.

The length of rotation cycle was previously included in models to study each set of data—control and molasses. In these analyses rotation cycle had no effect and this was also true when the two sets of data were combined. Rotation cycle was then deleted from the model that became Equation 4.

Although molasses had no effect as compared to control, the observation from Valle (1977) that the grazing animals showed great greediness for the forage just after it was sprayed with molasses was also observed during the year of 1977. It is believed that the lack of effect of sprayed molasses is due to low interest of the animals to graze smutgrass. It was observed that the animals grazed first the most palatable forages. Apparently these forages became more palatable when sprayed with molasses. Consequently, these forages were grazed out before the animals had to graze smutgrass but by then the sprayed molasses had dried out and lost its appeal to the cattle. This is similar to the results of O'Bryan (1960) who observed that the application of supplements on unpalatable grasses did not

prevent the selective grazing habit of the animals and that the higher protein containing forages were grazed first. It is also in agreement with Mostert (1959) and other authors who recommended the use of molasses in small strips to avoid waste.

Effect of Grazing Pressure

Since grazing pressure was the principal factor affecting the observed reduction in smutgrass ground cover [the linear and quadratic effects of grazing pressure for the two equations derived from Equation 4 were both significant (P = 0.0001)], the data were fitted to the quadratic model as follows:

$$\hat{Y}_{i1} = b_o + b_1X_1 + b_{11}X_1^2 + E_{i1} \qquad (5)$$

where $\hat{Y}_{i1}$ = estimated response in smutgrass ground cover (for $\hat{Y}_{11}$ = spring and $\hat{Y}_{21}$ = fall)

X_1 = grazing pressure levels,

b_{ij} = regression coefficients, and

E_{i1} = experimental error.

This model is, in fact, a reduced model resulting from Equation 3 after the length of rotation cycle factor was deleted.

When the spring-collected data were fitted to Equation 5., the following result was found: $\hat{Y}_{11} = -6.668 + 10.125\ X_1 - 1.848\ X_1^2$.

The coefficient of determination for this equation was $r^2 = 0.56$ and the standard error of estimate $s_{y \cdot x} = 2.42\%$.

The fall-collected data when fitted to Equation 5 resulted in the following:

$$\hat{Y}_{21} = -5.406 + 10.437\ X_1 - 2.375\ X_1^2$$

with the coefficient of determination $r^2 = 0.70$ and the standard error of estimate $s_{y \cdot x} = 1.56\%$.

The quadratic model presented in Equation 5 does not reflect the expected fact that the amount of ground cover should level off at light grazing pressures. The quadratic model implies that the ground cover increases (or decreases if $b_{11} < 0$) as X_1 increases. For this reason, the following exponential model

$$\hat{Y}_{i1} = a + be^{-cX_1} + E_{i1} \qquad (6)$$

was used to relate ground cover to grazing pressure.

In the above exponential model

$\hat{Y}_{i1}$ = estimated response in smutgrass ground cover (for $\hat{Y}_{11}$ = spring and $\hat{Y}_{21}$ = fall

X_1 = grazing pressure level,

a = maximum smutgrass ground cover when $X_1 \to \infty$

a+b = minimum smutgrass ground cover when $X_1 = 0$,

c = a constant affecting the rate at which smutgrass ground cover decreases as the grazing pressure increases (or the residual dry matter decreases), and

E_{i1} = experimental error.

Effect of Grazing Pressure in Spring

When the spring data were fitted to Equation 6, the following result was obtained:

$$\hat{Y}_{11} = 6.235 - 26.198e^{-1.873\ X_1}$$

The coefficient of determination for this equation was $r^2 = 0.51$ and the standard error of estimate was $s_{y \cdot x} = 2.58\%$. As it was expected, these two indicators of the adequacy of Equation 6 are very similar to those found for the Equation 5 for the spring data. It was observed that the variances of $\hat{Y}_{11}$ were markedly increased with increases of of $\hat{Y}_{11}$ values. To normalize the variances of $\hat{Y}_{11}$ for all levels of grazing pressure its values were transformed to the logarithmic scale after adding 1 to Y_{11} to avoid the zero values observed for smutgrass ground cover. The transformed values were fitted to equation

$$\log_e(\hat{Y}_{i1} + 1) = a + be^{-cX_1} + E_{i1} \qquad (6a)$$

When the spring data was fitted to Equation 6a, it gave the following result:

$$\log_e(\hat{Y}_{11} + 1) = 1.989 - 9.428e^{-2.177\ X_1}$$

The coefficient of determination then obtained was $r^2 = 0.75$ and the standard error of estimate was $s_{y \cdot x} = 0.43\%$.

The curves generated from the Equations 6 and 6a for spring data are presented in Figs. 3 and 4, respectively. It can be seen from Figs. 3 and 4 that smutgrass ground cover decreased sharply at grazing pressures between 2.11

and 0.79 metric ton RDM/ha and that smutgrass coverage was about constant for the grazing-pressure levels from 2.11 to 3.76 metric tons RDM/ha. This indicates that the grazing pressure level dictates the rate of reduction of smutgrass to be achieved. When the highest level of grazing pressure (equivalent to 0.79 metric ton RDM/ha in 1976) was imposed, control of smutgrass was almost complete—the initial smutgrass was reduced from 16.33% initial coverage to 0.24% as calculated by Equation 6a. Also, data in Figs. 3 and 4 indicate that smutgrass control was linearly reduced as the grazing pressure levels were decreased to the equivalent to 2.11 metric tons RDM/ha. From this level to the lowest level of grazing pressure observed in 1976 equivalent to 3.76 metric tons RDM/ha (Table 3), the reduction in smutgrass was smaller but still marked from the initial 16.33 to 4.79% as calculated by Equation 6a.

The point 2.11 metric tons RDM/ha was determined by the two-stage method which is the result of fitting the data to two linear equations using the Marquandt method as described by Barr et al. (1976). This method gave 2.11 as the breaking point of the two lines and the equations:

$$\hat{Y}_{11} = -3.243 + 4.479\ X_1 \qquad (7)$$

and

$$\hat{Y}_{11} = 6.20 \qquad (7a)$$

with the coefficient of determination $r^2 = 0.54$ and the standard error of estimate $s_{y \cdot x} = 2.49\%$.

Figure 3. Influence of grazing pressure upon the percent smutgrass ground cover, spring 1977, showing the plots of the two-stage and exponential models.

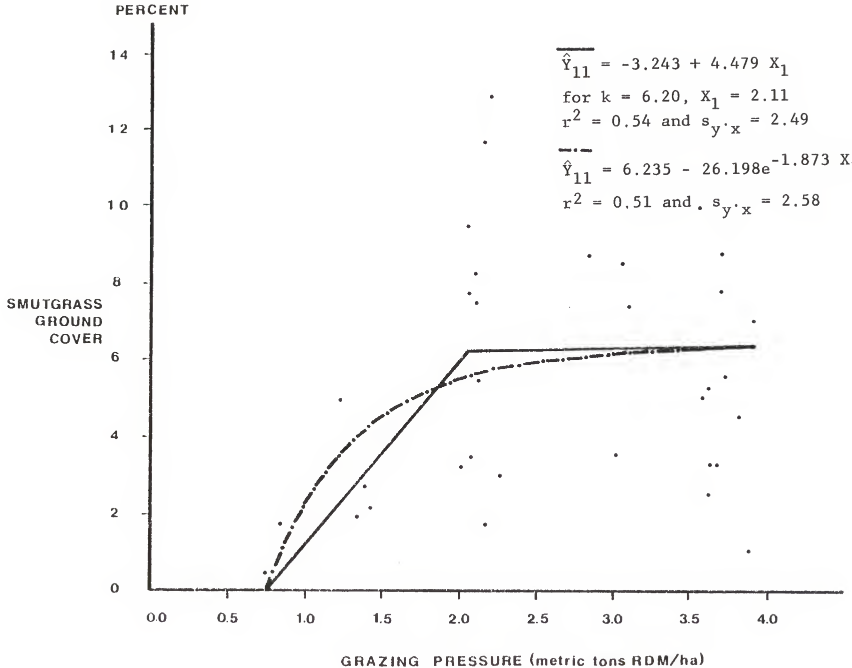
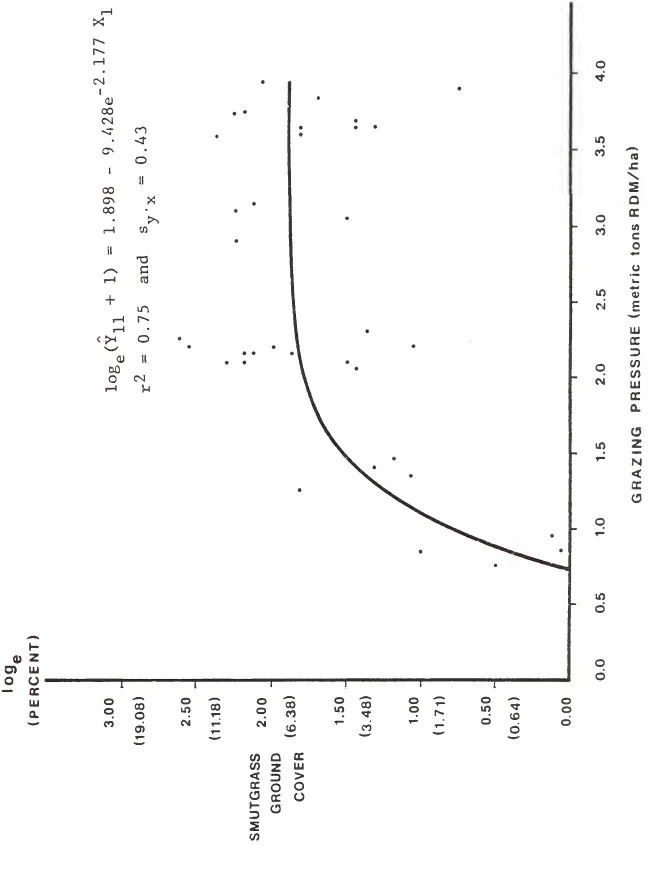

PERCENT
14
12
10
8
6
4
2
0
SMUTGRASS GROUND COVER
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
GRAZING PRESSURE (metric tons RDM/ha)
$\hat{Y}_{11} = -3.243 + 4.479\ X_1$
for $k = 6.20,\ X_1 = 2.11$
$r^2 = 0.54$ and $s_{y \cdot x} = 2.49$
$\hat{Y}_{11} = 6.235 - 26.198e^{-1.873\ X_1}$.
$r^2 = 0.51$ and $s_{y \cdot x} = 2.58$

Figure 4. Influence of grazing pressure upon the percent smutgrass ground cover, spring 1977, $\hat{Y} = \log_e$ transformations and equivalent percentages.



$\log_e(\hat{Y}_{11} + 1) = 1.898 - 9.428e^{-2.177\ X_1}$
$r^2 = 0.75$ and $s_{y \cdot x} = 0.43$
$\log_e$ (PERCENT)
3.00 (19.08)
2.50 (11.18)
2.00 (6.38)
1.50 (3.48)
1.00 (1.71)
0.50 (0.64)
0.00
SMUTGRASS GROUND COVER
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
GRAZING PRESSURE (metric tons RDM/ha)

Therefore, 6.20 is the constant (k) percentage of smutgrass ground cover for grazing pressures between 2.11 (also called the breaking point) and 3.76 metric tons RDM/ha. The curves generated from these equations (7 and 7a) are presented in Fig. 3.

These results are in agreement with results reported by Valle (1977) who indicated that smutgrass ground cover was reduced as grazing pressure increased, but are in disagreement with Bryan (1970) and Cameron and Cannon (1970) who mentioned increases in weed population under heavy grazing pressures.

Effect of Grazing Pressures in Fall

By fitting the fall-collected data to Equation 6, the following result was found:

$$\hat{Y}_{21} = 6.078 - 17.807e^{-1.768\ X_1}$$

The coefficient of determination for this equation was $r^2 = 0.69$ and the standard error of estimate $s_{y \cdot x} =$ 1.59%. As for the spring data the $\hat{Y}_{21}$ values were added to 1 and transformed to the logarithmic scale as $\log_e(\hat{Y}_{21} + 1)$ and also fitted to Equation 6a. When this equation was resolved for the fall data the following result was found:

$$\log_e(\hat{Y}_{21} + 1) = 1.936 - 6.970e^{-2.221\ X_1}$$

The coefficient of determination was $r^2 = 0.86$ and the standard error of estimate was $s_{y \cdot x} = 0.29\%$. The generated curves from Equations 6 and 6a for the fall data are

Figure 5. Influence of grazing pressure upon the percent smutgrass ground cover, fall 1977, showing the plots of the two-stage and exponential models.

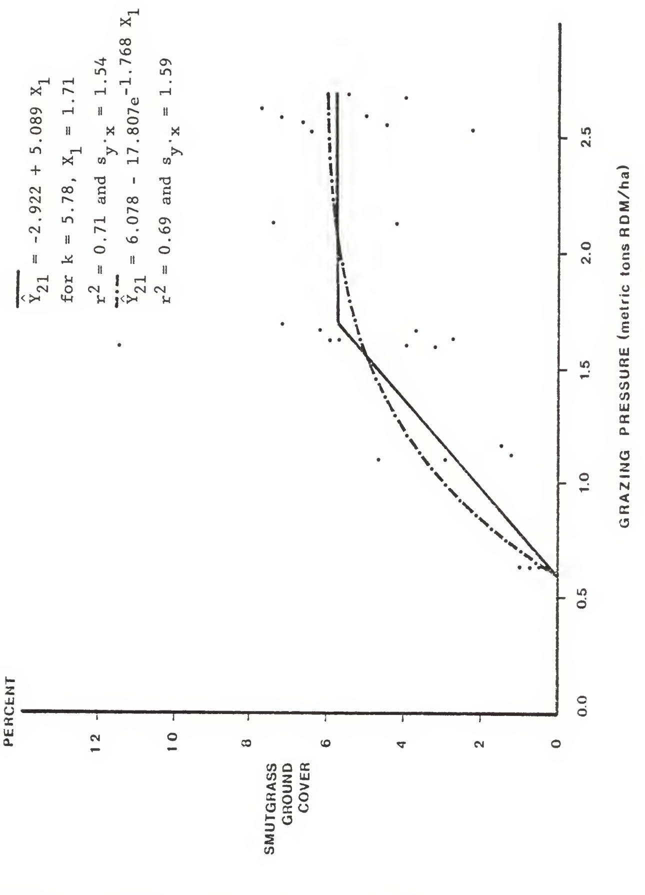
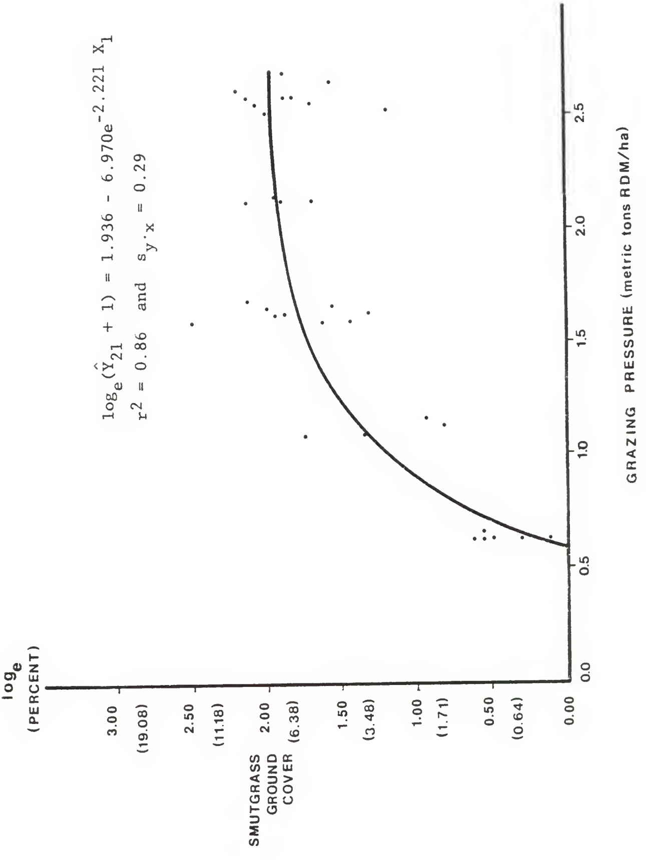

PERCENT
SMUTGRASS GROUND COVER
0
2
4
6
8
10
12
0.0
0.5
1.0
1.5
2.0
2.5
GRAZING PRESSURE (metric tons RDM/ha)
$\hat{Y}_{21} = -2.922 + 5.089 X_1$
for k = 5.78, $X_1 = 1.71$
$r^2 = 0.71$ and $s_{y \cdot x} = 1.54$
$\hat{Y}_{21} = 6.078 - 17.807e^{-1.768 X_1}$
$r^2 = 0.69$ and $s_{y \cdot x} = 1.59$

Figure 6. Influence of grazing pressure upon the percent smutgrass ground cover, fall 1977, $\hat{Y} = \log_e$ transformations and equivalent percentages.



$\log_e(\hat{Y}_{21} + 1) = 1.936 - 6.970e^{-2.221\ X_1}$
$r^2 = 0.86$ and $s_{y \cdot x} = 0.29$
$\log_e$
(PERCENT)
SMUTGRASS GROUND COVER
3.00
(19.08)
2.50
(11.18)
2.00
(6.38)
1.50
(3.48)
1.00
(1.71)
0.50
(0.64)
0.00
0.0
0.5
1.0
1.5
2.0
2.5
GRAZING PRESSURE (metric tons RDM/ha)

presented in Figs. 5 and 6. It can be observed from data in Figs. 5 and 6 that the pattern shown in the spring was maintained. Hence, the highest grazing pressure imposed equivalent to 0.67 metric ton RDM/ha kept the smutgrass almost fully controlled. Under this grazing pressure, smutgrass reduction was 98.5% in relation to the initial coverage, i.e., smutgrass was reduced from 16.33% at the beginning of the experiment to 0.25% as calculated by Equation 6a for the fall of 1977. As shown for the spring, the fall data also show that smutgrass control was reduced linearly as the grazing pressure was decreased (RDM increased) from the equivalent of 1.71 metric tons RDM/ha and became constant from this grazing pressure level to the lowest grazing pressure level observed in 1977, equivalent to 2.67 metric tons RDM/ha (Table 4). Smutgrass ground cover at this level of grazing pressure was 5.4% as calculated by Equation 6a.

The grazing pressure 1.71 metric tons RDM/ha is the breaking point in which the smutgrass ground cover ($\hat{Y}_{21}$) became constant as calculated by the two-stage method.

The results obtained by this method gave:

$$\hat{Y}_{21} = -2.922 + 5.089\ X_1 \tag{7}$$

and

$$\hat{Y}_{21} = 5.78 \tag{7a}$$

with the coefficient of determination $r^2 = 0.71$ and the standard error of estimate $s_{y \cdot x} = 1.54\%$.

The plot of the lines representing Equations 7 and 7a using the fall data are presented in Fig. 5. In Table 5 these equations as well as all other fitted equations in this text are presented.

For the grazing pressure levels in the range 1.71 to 2.67 metric tons RDM/ha, smutgrass ground cover of 5.78% represents a reduction of 65.4% in relation to the initial coverage, i.e., smutgrass was reduced from 16.33 to 5.78%, respectively, initial and fall of 1977 coverages. Between spring and fall of 1977, the reduction in smutgrass at the $\hat{Y}_{i1} = k$ was in the order of 6.8%, i.e., smutgrass was reduced from 6.20 to 5.78%, respectively, k, in spring and fall of 1977.

If the reduction in smutgrass ground cover is calculated for the whole experiment, it is found that 73.8% was reduced during the first year and 76.0% during the 2 years of the experiment in relation to the initial coverage, i.e., smutgrass was reduced from the initial 16.33 to 4.27% during the first year and from 16.33 to 3.91% during the 2 years. Therefore, during the second year the reduction in smutgrass ground cover was 9.2%, i.e., from 4.27 to 3.91% which are the means for the spring and fall 1977, respectively.

The results obtained in this experiment showed that grazing pressure is a very effective tool to control smutgrass. It was demonstrated that the speed of reduction in smutgrass ground cover was dependent on the level of grazing pressure imposed. Further, a high level of grazing

TABLE 5. List of fitted models showing the estimated values, the coefficients of determination, and the standard error of estimate for each equation.

Equation	r^2	$s_{y \cdot x}$
1. Estimated residual dry matter:		
$\hat{Y}_a = 14.95\ X_a$	0.90	34.70
2. Estimated basal area ground cover		
$\hat{Y}_b = 0.45\ X_b$	0.88	2.50
3. Response surface model for smutgrass ground cover		
$\hat{Y}_{112} = -7.014 + 10.717\ X_1 + 0.014\ X_2 - 1.841\ X_1^2 - 0.022\ X_1X_2$	0.63	2.29
$\hat{Y}_{212} = -5.891 + 11.249\ X_1 + 0.010\ X_2 - 2.443\ X_1^2 - 0.021\ X_1X_2$	0.75	1.49
4. Estimating molasses effect		
$\hat{Y}_{113} = -7.219 + 10.786\ X_1 + 0.529\ X_3 - 1.774\ X_1^2 - 0.650\ X_1X_3$	0.59	2.41
$\hat{Y}_{213} = -5.616 + 11.095\ X_1 + 0.194\ X_3 - 2.328\ X_1^2 - 0.534\ X_1X_3$	0.72	1.55
5. Quadratic model for smutgrass ground cover reduction due to grazing pressure		
$\hat{Y}_{11} = -6.668 + 10.125\ X_1 - 1.848\ X_1^2$	0.56	2.42
$\hat{Y}_{21} = -5.406 + 10.437\ X_1 - 2.375\ X_1^2$	0.70	1.56
6. Exponential model for smutgrass ground cover reduction due to grazing pressure		
$\hat{Y}_{11} = 6.235 - 26.198e^{-1.873\ X_1}$	0.51	2.58
$\hat{Y}_{21} = 6.078 - 17.807e^{-1.768\ X_1}$	0.69	1.59
6a. Exponential model using $\log_e(\hat{Y}_{i1} + 1)$		
$\log_e(\hat{Y}_{11} + 1) = 1.898 - 9.428e^{-2.177\ X_1}$	0.75	0.43
$\log_e(\hat{Y}_{21} + 1) = 1.936 - 6.970e^{-2.221\ X_1}$	0.86	0.29
7. Two stage model		
$\hat{Y}_{11} = -3.243 + 4.479\ X_1$ for $k = 6.20$, $X_1 = 2.11$	0.54	2.49
$\hat{Y}_{21} = -2.922 + 5.089\ X_1$ for $k = 5.78$, $X_1 = 1.71$	0.71	1.54

* $\hat{Y}_{1..}$ = spring and $\hat{Y}_{2..}$ = fall

pressure cannot only control the smutgrass in an infested area, but also can keep an area from smutgrass infestation whether it was controlled or already smutgrass-free. Therefore, it can be inferred that smutgrass infestation is a consequence of mismanagement. This is in agreement with Morrow and McCarty (1976) who stated that weedy pastures are a result of mismanagement.

If rapid control of smutgrass by grazing is desired, grazing pressure levels to be imposed should be higher than the equivalent of 1.0 metric ton RDM/ha. In this case, care should be taken with the animals which will lose weight if the pasture is highly infested. However, if gradual reduction is the goal, grazing pressures around the equivalent to 1.5 metric ton RDM/ha could be recommended, since grazing pressures of this level will not harm the grazing animals as would the higher level equivalent to 0.5 metric ton RDM/ha projected for use in this experiment.

On the other hand, in order to control smutgrass in infested pastures, light grazing pressure levels like the one that allowed an equivalent of 2.5 metric tons RDM/ha, or higher RDM, are not recommended because the degree of reinfestation would be very high due to seeds already in the ground plus seeds that are produced during the process of control. This is the situation that has happened with other methods of control such as those reported by McCaleb et al. (1963) and other workers.

The beneficial effects of controlling smutgrass were observed in this experiment. Bahiagrass population on the plots where smutgrass was mostly controlled increased about ten fold whereas in the plots in which smutgrass was less reduced, such as the ones receiving grazing pressure equivalent to 2.5 metric tons RDM/ha, the bahiagrass population remained the same or increased very little.

The trend observed with bahiagrass was also observed for white clover during the cool seasons of 1976/77 and 1977/78. These results are in agreement with Morrow and McCarty (1976), Scholl and Brunk (1962), and other authors who reported large increases in forage production by the control of weeds. It is also in agreement with Torssell et al. (1976) who observed that some species are mutually exclusive when growing in associations. Thus, it is evident that smutgrass is stronger than the desirable species growing in smutgrass-infested pastures. Besides, being unpalatable to grazing animals, smutgrass development is favored to the detriment of the desirable forage crops. Therefore, it is very necessary to impose some sort of control on smutgrass in order to improve the development of the desirable forage species. Grazing can be used successfully for this purpose as indicated by this research. Also, as stated by Bendall (1973), grazing is a cheap method to control weeds and can be incorporated into the farm management system very easily.

CONCLUSIONS

The experimental design was a modified central composite in two factors (rotation cycle and grazing pressure) each at five levels arranged in a response surface design. Combinations of length of rotation cycle and grazing pressure were superimposed upon three main treatments, from which two—control and molasses—are reported.

After 2 years of imposing the two above mentioned factors upon the two treatments on smutgrass, it was concluded that grazing pressure is a very effective tool to control this grass, but the length of rotation cycle or spraying with molasses did not affect smutgrass.

Grazing pressure substantially reduced smutgrass with the highest level being the most effective among the five levels imposed. Indeed, for the grazing pressure equivalent to the 0.5 metric ton RDM/ha, smutgrass was 98.5% controlled by the end of the first year of the experiment, and under this grazing-pressure level, the smutgrass was kept out of the pasture during the second year. For the lowest grazing-pressure level imposed during the first year, equivalent to 3.7 metric tons RDM/ha, the reduction in smutgrass was of the order of 62.1%, i.e., it was reduced from 16.33% initial smutgrass ground cover to 6.20% as observed in the spring of 1977. This grazing pressure was increased during the

second year to allow 2.5 metric tons RDM/ha but only slight further reduction in smutgrass ground cover was observed. Coverage of 5.78% was observed in the fall of 1977. Also, further reduction was observed in the second year of the experiment for all grazing-pressure levels.

Since the reduction in smutgrass ground cover was greater for grazing pressures higher than the equivalent to 1.71 metric tons RDM/ha, a grazing pressure that allows approximately 1.5 metric tons RDM/ha is recommended for use in the farm system to control smutgrass. If grazing pressure levels higher than the equivalent of 1.0 metric ton RDM/ha are to be used, care should be taken with the grazing animals, mainly during the first year because the smutgrass is only rarely grazed and the animals will lose weight in direct proportion to the degree of smutgrass infestation. On the other hand, grazing-pressure levels that allow above 2.5 metric tons RDM/ha would not be recommended because of the reestablishment of smutgrass due to the large amount of seeds produced annually. The degree of reinfestation will jeopardize the control to be achieved. To control smutgrass by grazing, the most important point is to impose grazing-pressure levels that force the animals to graze the smutgrass in direct proportion to the speed of control desired.

The beneficial effects of controlling smutgrass were observed on the desirable species (namely, bahiagrass and white clover) present at the experimental site in both

summer and winter. A sharp increase in bahiagrass population was observed in the summer of 1977 which was directly proportional to the decrease of smutgrass. The population of white clover was also increased in both winters 1976/77 and 1977/78.

APPENDIX 1

CALENDAR OF ACTIVITIES OF THE EXPERIMENT

Table 6 - Calendar of grazing periods showing the starting dates, and the ending dates which were also disk-meter measurement dates.

	Plot #	R.C.+ (days)	G.P.*	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
CONTROL	5	14	1.0																									g				d	
	45	14	2.0																		g	d											
	48	42	1.0																												g		
	3	42	2.0																														
	58	0	0.5																														
	68	0	0.5																										g				
	27	0	1.5																		g	d											
	73	0	1.5																												g		
	7	0	2.5																		g									d			
	44	0	2.5																				g										d
	5	28	0.5																					g				d					
	38	28	0.5																														
	56	28	1.5																				g		d								
	67	28	1.5																														
	53	28	2.5																				g	d									
	80	28	2.5																														
	1	56	0.5																												g		
	60	56	0.5																														
	71	56	1.5																									g			d		
	77	56	1.5																														
	46	56	2.5																											g	d		
	65	56	2.5																														
MOLASSES	52	14	1.0																									g				d	
	15	14	2.0																		g	d											
	32	42	1.0																													g	
	14	42	2.0																														
	43	0	0.5																				g				d						
	49	0	0.5																										g				
	22	0	1.5																		g											d	
	74	0	1.5																													g	
	64	0	2.5																										g				
	72	0	2.5																										g				
	20	28	0.5																						g				d				
	69	28	0.5																														
	30	28	1.5																				g	d									
	42	28	1.5																														
	11	28	2.5																				g	d									
	82	28	2.5																														
	18	56	0.5																													g	
	36	56	0.5																														
	9	56	1.5																								g			d			
	78	56	1.5																														
	25	56	2.5																											g	d		
	62	56	2.5																														

(All dates are in APRIL.)

+ length of rotation cycle
* Grazing pressure in metric tons/ha of residual dry matter

g = grazing period starts
d = grazing period ends

Table 6 - continued

	PLOT #	R.C.+ (days)	G.P.*	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
				MAY																														
	5	14	1.0																							g	d							
	45	14	2.0		g	d																												
	48	42	1.0	d																														
	3	42	2.0													g		d																
	58	0	0.5	d	d																			g		d								
C	68	0	0.5			d																		g		d								
O	27	0	1.5		g											d							g		d									
	73	0	1.5					d																g								d		
N	7	0	2.5									g		d									g				d							
T	44	0	2.5															g						d										
R	6	28	0.5																				g		d									
O	38	28	0.5					g				d																						
	56	28	1.5																		g		d											
L	67	28	1.5			g		d																										
	53	28	2.5																		g		d											
	80	28	2.5			g		d																										
	1	56	0.5					d																										
	60	56	0.5																											g				
	71	56	1.5																															
	77	56	1.5																							g	d							
	46	56	2.5																															
	66	56	2.5																									g		d				
	52	14	1.0																							g	d							
	15	14	2.0	g	d															•	d												g	
	32	42	1.0	d																														
	14	42	2.0													•	d																	
M	43	0	0.5																				g			d								
	49	0	0.5	d																					g		d							
O	22	0	1.5																						g							d		
L	74	0	1.5											d										g										d
	64	0	2.5								d														g							d		
A	72	0	2.5						d															g									d	
S	20	28	0.5																				g			d								
S	69	28	0.5					g				d																						
	30	28	1.5																		g		d											
E	42	28	1.5			g		d																										
S	11	28	2.5																		g	d												
	82	28	2.5			g	d																											
	18	56	0.5					d																										
	36	56	0.5																											g				
	9	56	1.5																															
	78	56	1.5																							g	d							
	26	56	2.5																															
	62	56	2.5																									g		d				

+ Length of rotation cycle
* Grazing pressure in metric tons/ha of residual dry matter

g = grazing period starts
d = grazing period ends

Table 6 - continued

	Plot #	R.C.+ (days)	G.P.*	JUNE 01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
	5	14	1.0							g		d											g			d							
	45	14	2.0			d										g			d											g	d		
	48	42	1.0										g			d																	
	3	42	2.0																								g						
CONTROL	58	0	0.5					g						d												g						d	
	68	0	0.5								g							d								g		d					
	27	0	1.5						g							d									g							d	
	73	0	1.5										g			d													g				
	7	0	2.5							g								d												g			
	44	0	2.5								g											d											
	6	28	0.5																	g			d										
	38	28	0.5			g			d																								
	56	28	1.5															g		d													
	67	28	1.5	g		d																											
	53	28	2.5															g		d												g	
	80	28	2.5	g		d																										g	
	1	56	0.5																														
	60	56	0.5	d																							g				d		
	71	56	1.5																														
	77	56	1.5																				g				d						
	46	56	2.5																														
	66	56	2.5																						g					d			
	52	14	1.0							g		d											g			d							
	15	14	2.0		d											g		d												g		d	
	32	42	1.0										g					d															
	14	42	2.0																								g					d	
MOLASSES	43	0	0.5							g		d																		g		d	
	49	0	0.5										g			d																	
	22	0	1.5										g									d										g	
	74	0	1.5										g							d												d	
	64	0	2.5										g						d											g			
	72	0	2.5										g							d													
	20	28	0.5																	g			d										
	69	28	0.5			g			d																								
	30	28	1.5															g		d													
	42	28	1.5	g		d																											
	11	28	2.5															g		d												g	
	82	28	2.5	g		d																										g	
	18	56	0.5																														
	36	56	0.5	d																							g					d	
	9	56	1.5																														
	78	56	1.5																				g				d						
	26	56	2.5																														
	62	56	2.5																						g				d						

+ length of rotation cycle
* Grazing pressure in metric tons/ha of residual dry matter

g = grazing period starts
d = grazing period ends

Table 6 - continued

	PLOT	R.C.+	G.P.*	JULY																														
	#	(days)		01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
	5	14	1.0						g		d										g							d						
	45	14	2.0											g				d										g		d				
	48	42	1.0																						g					d				
	3	42	2.0				d																											
	58	0	0.5							g			d															g						
C	68	0	0.5								g						d														g			
O	27	0	1.5													g							d										g	
	73	0	1.5					d																										
N	7	0	2.5					d												g					d									
T	44	0	2.5						g			d										g						d						
R	6	28	0.5															g							d									
O	38	28	0.5		g					d																						g		
	56	28	1.5													g							d											
L	67	28	1.5					d																						g				
	53	28	2.5													g							d											
	80	28	2.5				d																							g				d
	1	56	0.5																															
	60	56	0.5																						g						d			
	71	56	1.5																															
	77	56	1.5																		g				d									
	46	56	2.5																															
	66	56	2.5																				g						d					
	52	14	1.0						g			d									g							d						
	15	14	2.0											g				d										g		d				
	32	42	1.0																						g						d			
	14	42	2.0																															
	43	0	0.5						g					d														g						
H	49	0	0.5						g				d															g						
O	22	0	1.5										d																					
	74	0	1.5					d													g									d				
L	64	0	2.5							d																								
A	72	0	2.5		g								d																					
S	20	28	0.5															g							d									
S	69	28	0.5	g							d																					g		
	30	28	1.5													g					d													
E	42	28	1.5				d																							g				
S	11	28	2.5													g		d																
	82	28	2.5			d																								g				d
	18	56	0.5																															
	36	56	0.5																						g									
	9	56	1.5																															
	78	56	1.5																		g							d						
	26	56	2.5																															
	62	56	2.5																				g					d						

+ Length of rotation cycle
* Grazing pressure in metric tons/ha of residual dry matter

g = grazing period starts
d = grazing period ends

Table 6 - continued

	PLOT #	R.C.[+] (days)	G.P.[*]	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
	5	14	1.0	g				d										g											d			g	d	
	45	14	2.0								•							d							g				d					
	48	42	1.0																															
	3	42	2.0					g				d																						
CONTROL	58	0	0.5																		g						d							
	68	0	0.5						d						g					d											g			
	27	0	1.5								d										•							d						
	73	0	1.5		g						d																							
	7	0	2.5	g										d									g				d							
	44	0	2.5				g					d							g						d									
	6	28	0.5												g							d												
	38	28	0.5				d																						g					
	56	28	1.5										g					d																
	67	28	1.5		d																						g							
	53	28	2.5										g			d																		
	80	28	2.5																								g							d
	1	56	0.5																			g										d		
	60	56	0.5																															
	71	56	1.5															g								d								
	77	56	1.5																															
	46	56	2.5																	g					d									
	66	56	2.5																															
	52	14	1.0	g	d													g			d											g		
	15	14	2.0								g			d											g			d						
	32	42	1.0																															
	14	42	2.0					g						d																				
MOLASSES	43	0	0.5	d											g				d														g	
	49	0	0.5					d																		g								
	22	0	1.5	g																	d													g
	74	0	1.5								g				d											g						d		
	64	0	2.5	g										d															g					d
	72	0	2.5	g									d													g					d			
	20	28	0.5												g							d												
	69	28	0.5				d																						g					
	30	28	1.5										g					d																
	42	28	1.5	d																							g					d		
	11	28	2.5										g					d																
	82	28	2.5																								g					d		
	18	56	0.5																			g										d		
	36	56	0.5				d																											
	9	56	1.5															g										d						
	78	56	1.5																															
	26	56	2.5																	g					d									
	62	56	2.5																															

+ length of rotation cycle
* Grazing pressure in metric tons/ha of residual dry matter

g = grazing period starts
d = grazing period ends

Table 6 - continued

	PLOT #	R.C.+ (days)	G.P.*	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
	5	14	1.0												g		d												g			d	
	45	14	2.0						g			d										g							d				
	48	42	1.0		g					d																							
	3	42	2.0																g						d								
CONTROL	58	0	0.5										g					d											g			d	
	68	0	0.5			d								g		d													g			d	
	27	0	1.5	g			d											g	d										g				d
	73	0	1.5						d															g			d						
	7	0	2.5	g								d											g										d
	44	0	2.5	g				d										g				d											
	6	28	0.5									g			d																		
	38	28	0.5		d																					g			d				
	56	28	1.5							g						d																	
	67	28	1.5	d																				g				d					
	53	28	2.5							g			d																				
	80	28	2.5																					g			d						
	1	56	0.5																														
	60	56	0.5																g								d						
	71	56	1.5																														
	77	56	1.5												g					d													
	46	56	2.5																														
	66	56	2.5														g					d											
	52	14	1.0			d									g		d																
	15	14	2.0						g			d										g		d									
	32	42	1.0		g						d																						
	14	42	2.0																g						d								
HOLCASSES	43	0	0.5			d												g					d									g	d
	49	0	0.5	d									g			d													g				d
	22	0	1.5								d																		g				
	74	0	1.5													g							d										
	64	0	2.5													g								d									
	72	0	2.5													g									d								
	20	28	0.5									g			d																		
	69	28	0.5			d																				g			d				
	30	28	1.5							g					d																		
	42	28	1.5																					g		d							
	11	28	2.5							g					d																		
	82	28	2.5																					g			d						
	18	56	0.5																														
	36	56	0.5																g										d				
	9	56	1.5																														
	78	56	1.5												g							d											
	26	56	2.5																														
	62	56	2.5														g			d													

(Day columns 01–30: SEPTEMBER)

+ Length of rotation cycle
* Grazing pressure in metric tons/ha of residual dry matter

g = grazing period starts
d = grazing period ends

Table 6 - continued

	PLOT	R.C.+	G.P.*	OCTOBER																														
	#	(days)		01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
	5	14	1.0																															
	45	14	2.0			g		d																										
	48	42	1.0																g			d												
	3	42	2.0																															
CONTROL	58	0	0.5																															
	68	0	0.5																															
	27	0	1.5																															
	73	0	1.5																															
	7	0	2.5																	g		d												
	44	0	2.5																															
	6	28	0.5						g				d																					
	38	28	0.5																															
	56	28	1.5					g					d																					
	67	28	1.5																															
	53	28	2.5			g		d																										
	80	28	2.5																															
	1	56	0.5														g					d												
	60	56	0.5																															
	71	56	1.5										g							d														
	77	56	1.5																															
	46	56	2.5												g				d															
	66	56	2.5																															
	52	14	1.0																															
	15	14	2.0					g		d																								
	32	42	1.0																g			d												
	14	42	2.0																															
MOLASSES	43	0	0.5																															
	49	0	0.5																															
	22	0	1.5					d																										
	74	0	1.5																															
	64	0	2.5																															
	72	0	2.5																			g		d										
	20	28	0.5						g				d																					
	69	28	0.5																															
	30	28	1.5								g		d																					
	42	28	1.5																															
	11	28	2.5					g			d																							
	82	28	2.5																															
	18	56	0.5																	g		d												
	36	56	0.5																															
	9	56	1.5										g							d														
	78	56	1.5																															
	26	56	2.5												g					d														
	62	56	2.5																															

+ length of rotation cycle
* Grazing pressure in metric tons/ha of residual dry matter

g = grazing period starts
d = grazing period ends

Table 7. Calendar of line transect measurements for each plot. Spring and fall 1977.

	PLOT #	R.C.+ (days)	G.P.*	JUNE								JULY							SEPTEMBER				OCTOBER												
				20	21	22	23	24	26	27	30	01	02	03	04	05	06	08	27	28	29	30	01	03	05	06	07	09	10	11	12	13	14	17	19
CONTROL	5	14	1.0								s																f								
	45	14	2.0														s												f						
	48	42	1.0			s																								f					
	3	42	2.0													s			f																
	58	0	0.5														s															f			
	68	0	0.5															s																f	
	27	0	1.5													s								f											
	73	0	1.5				s																												f
	7	0	2.5															s		f															
	44	0	2.5								s									f															
	6	28	0.5								s									f															
	38	28	0.5								s																f								
	56	28	1.5							s																						f			
	67	28	1.5															s														f			
	53	28	2.5							s																				f					
	80	28	2.5	s																													f		
	1	56	0.5												s								f												
	60	56	0.5													s																	f		
	71	56	1.5											s														f							
	77	56	1.5		s																														f
	46	56	2.5	s																									f						
	66	56	2.5									s																					f		
MOLASSES	52	14	1.0					s																						f					
	15	14	2.0		s																			f											
	32	42	1.0									s														f									
	14	42	2.0			s																f													
	43	0	0.5					s															f												
	49	0	0.5			s																								f					
	22	0	1.5		s																				f										
	74	0	1.5				s																												f
	64	0	2.5				s																											f	
	72	0	2.5										s													f									
	20	28	0.5					s																	f										
	69	28	0.5	s																														f	
	30	28	1.5		s																					f									
	42	28	1.5						s																				f						
	11	28	2.5						s												f														
	82	28	2.5	s																											f				
	18	56	0.5					s																f											
	36	56	0.5									s																f							
	9	56	1.5						s												f														
	78	56	1.5							s																	f								
	26	56	2.5			s																			f										
	62	56	2.5										s									f													

+ Length of rotation cycle
* Grazing pressure in metric tons/ha of residual dry matter

s = spring transect reading
f = fall transect reading

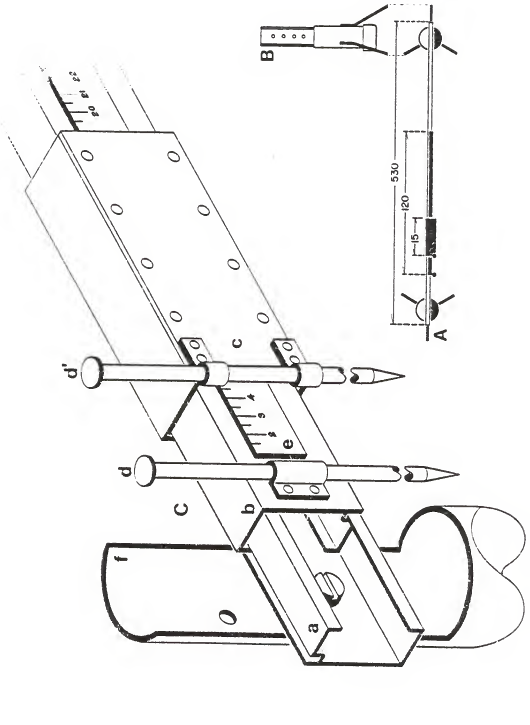
APPENDIX 2

THE TRANSECTOR: AN INEXPENSIVE DEVICE USED TO MEASURE GROUND COVER IN THE EXPERIMENT

A need for an apparatus capable of simplifying the reading and recording of the smutgrass ground cover in this experiment prompted the development of the transector (Andrade and Ocumpaugh, 1979). This is a lightweight, simple inexpensive device that uses the line interception method as developed by Canfield (1941). The transector allows very rapid field measurements and decreases subsequent computation time, while maintaining the accuracy shown in the Canfield method.

The essential materials to build the device are two pieces of 2.54 x 5.08 cm (1" x 2") aluminum patio extrusion. This patio extrusion should be smooth open-back with a round spline groove. For our purposes, one piece of the patio extrusion was 5.3 m long and the other 1.2 m. This allowed readings to be made along a 5-m transect without moving the whole transector. The transector is mounted on small tripods at each end as shown in Fig. 5 below, A & B, such that the spline groove in the long (fixed) patio extrusion is at the top (C in Fig. 5). The tripods may be of any material; however, it was found that they need to be weighted near the bottom to stabilize the transector. The legs of the tripods should be attached such that they do not extend into the area to be measured. The vertical part of the tripod should be about 50-cm long with holes drilled every 5 to 10 cm, to allow for adjustment in the height of attachment of the transector. Each tripod is attached to the transector with a small bolt and wing nut.

Figure 7. Schematic of the transector showing a top view (A), the tripod (B), and front view (C), as it is set in the field (all measurements given in cm).



A
B
a
b
c
C
d
d'
e
f
530
120
15

The short (1.2 m) patio extrusion is then inverted and placed in the fixed piece as shown in Fig. 5-c, so that it will slide freely. A pin holder for the adjustable pin (pin may be a long nail or made any length from bolt stock) is affixed with pop rivets near the left end of the short (1.2 m) patio extrusion, as in Fig. 5-c. A metal meter stick, or other similar device (Fig. 5-e), is attached with pop rivets to the short patio extrusion in such a way that the "0" end lines up with the center of the left adjustable pin (Fig. 5-d). A "collar" is fitted so that it will slide freely over the two pieces of patio extrusion. This collar may be made of any material that is light and durable (such as aluminum, plexiglas, fiber glass, or any combination thereof). The collar should be about 15-cm long to provide stability to the right adjustable pin (Fig. 5-d'). Another pin holder is attached with pop rivets to the collar, such that the center of the pin is aligned with the left end of the collar.

The pin holders are fitted to the pins such that they may be adjusted up or down as needed, but not so loose that they fall down freely.

The transector may be transported to and from the field by constructing two posts to fit in the front and rear stake pockets of a pickup truck so that it could be mounted on them and extending over the cab. A third post attached to the front bumper will stabilize the transector in the front. The tripods should be removed when transporting the transector to and from the field.

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BIOGRAPHICAL SKETCH

João Monteiro de Sales Andrade was born in Fortaleza, Ceará, Brazil, on March 01, 1947.

He completed high school at the Liceu do Ceará, in Fortaleza, in 1965. In 1969, he received his Bachelor of Science degree in agronomy from the Escola de Agronomia da Universidade Federal do Ceará, in Fortaleza.

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He began developing research programs on pasture management in 1973 at the Programa Integrado de Pesquisa Agropecuaria do Estado de Minas Gerais (PIPAEMG) now Empresa de Pesquisa Agropecuaria de Minas Gerais (EPAMIG). In January of 1976 he began his academic program at the University of Florida for the degree of Doctor of Philosophy in agronomy under the sponsorship of EPAMIG-EMBRAPA (Empresa Brasileira de Pesquisa Agropecuaria), the official State of Minas Gerais and country-wide Brazilian agriculture research institutions, respectively.

He is a member of the Sociedade Brasileira de Zootecnia, American Society of Agronomy, Soil Science Society of America, and Soil and Crop Science Society of Florida.

He is married to Maria Augusta d'Alva Andrade, and they have three children, Patricia, Flavia, and João.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

G. O. Mott, Chairman
Professor of Agronomy

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Assistant Professor of Agronomy

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